gives a great number of examples; but although the processes for that purpose are easy, the difficulty consists wholly in finding the proper method of treating each individual case. The author hopes to lay before the Society, on a future occasion, an account of the principles on which this branch of analysis is founded.

Mr. Faraday's Eighth Series of Experimental Researches in Electricity was resumed and read in continuation.

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June 19, 1834.

FRANCIS BAILY, Esq., Vice-President, in the Chair.

The reading of Mr. Faraday's Eighth Series of Experimental Researches in Electricity was resumed and concluded.

This series is devoted to an investigation of the source, character and conditions of the electricity of the voltaic instrument, and is divided into five parts. In the first part, simple voltaic circles are considered; and at the outset, the great question of "whether the electricity is due to contact or chemical action?" is investigated and decided by apparently very conclusive evidence in favour of the latter. One principal experiment in favour of this decision is the following: A plate of zinc and a plate of platina were prepared; one end of each of these was put into a vessel containing a little dilute sulphuric acid or sulpho-nitric acid, and between the other ends was placed a piece of bibulous paper moistened in a solution of iodide of potassium: the two plates did not touch each other anywhere, but still the action of the end at the one extremity was able to induce the electro-chemical decomposition of the iodide of potassium at the other. That this decomposition was due to the chemical action of the acid was proved by removing the latter; for then the decomposition ceased. It was also farther proved by the appearance of the iodine against the *platina*; for it went there in consequence of the passage of a current (induced by the action of the acid) having the opposite direction to that which the solution of iodide would have produced had it been the only exciting body, and metallic contact had been allowed.

The opposition of the chemical affinities at the two places where the acid and the solution of the iodide are placed, is shown when the metal plates are allowed to touch each other in the middle; for then two opposite electric currents are produced, but that occasioned by the acid is the stronger. This opposition is farther shown in the manner in which the weaker set of affinities are overcome by the stronger (that is, those of the iodide and zinc by those of the acid and zinc); and this dependence and relation of the two explains at once the value of metallic contact; for if the solution of iodide of potassium be placed between platina and platina, one of those pieces of metal touching the zinc which is immersed in the acid, then the solution of iodide does not tend to throw an electric current into circulation, because it exerts no chemical action in either direction; and therefore

the powers active in the acid are more free to act, produce a stronger current, and effect decomposition more freely.

The chemical actions at the opposite ends of the metallic arrangement are so strongly associated and related, that in the most perfect form of experiment, action cannot occur at either end without also taking place at the other extremity to an exactly equivalent amount. This is considered by the author as the most convincing proof that in the voltaic pile the chemical and electric action are the same; that is, modes of exhibition of the same force, and as they are convertible into each other in exactly definite proportion, must have one common origin.

By using different fluids at the exciting place of action, currents of different intensity could be obtained: thus the current produced by the action of dilute sulphuric acid on zinc and platina could decompose elsewhere solution of iodide of potassium, fused protochloride of tin, or chloride of silver; but could not decompose water, muriatic acid, nitric, or the chloride or iodide of lead. Making the dilute sulphuric acid stronger, or using larger plates of zinc and platina, did not yield any advantage; but immediately that the chemical action on the zinc was increased in *intensity*, which could be done by adding only a few drops of nitric acid, then most of the latter bodies could be decomposed by a single pair of plates. A scale of initial intensities can in this way be obtained.

The electricity evolved in the voltaic pile is altogether due to that chemical action which takes place between the metal most easily acted upon and the element which unites with it; as, for instance, between the zinc and the oxygen of the water, or the chlorine of the muriatic acid, or the sulphur of hydrosulphurets, &c.; the after action of the acid in combining with the oxide, when that is the substance formed, adds nothing to the effect. The truth of this principle is deduced in the first place from the electricity evolved being the equivalent of the zinc oxidized; in the second, from the quantity of electricity being the same for the oxidation of a given quantity of zinc, whether the oxide formed is removed by an acid or an alkali; and it is supported by many other experimental reasons and proofs.

The view which the author takes of the identity of electrical and chemical action, leads him to admit that there are *two modes of action* in which the attractive power of the substances which ultimately combine, and by combining give the voltaic pile activity, can be exerted. Thus, taking zinc and platina as the two metals used, then the *third* substance must be an electrolyte; that is, a body which is decomposed when the electric current passes it; which cannot conduct the current unless it is at the same time decomposed; and which contains an element having such attraction for the zinc that the latter can take it from the element with which it is previously combined. Water is the electrolyte generally present in the voltaic pile.

Then, with respect to the attraction between the zinc and the oxygen of the water, we have it in our power to cause it to take place at once when the metal and water are in contact, the hydrogen being then set free; or we can, by using the precautions which the author

gives, cause that no action take place, unless a current be formed and the hydrogen be transferred to a distance, whilst the forces circulate in what is called the electric current. Placing the origin of the current in the chemical action, which yet could be thus virtually restrained unless the circuit was completed, the author expected to find a state of tension in the chemical or electrical forces *before* metallic contact was made or the circuit perfect, and was able at last to prove this most fully by obtaining an *electric spark* between two plates of different metals immersed in acid before they came in contact. This fact, with the former one of decomposition, fully proved that contact was not necessary to the production of the electricity in the voltaic pile.

The *second* part of this memoir contains an investigation of the following important points: namely, whether electrolytes could resist the action of an electric current if below a certain intensity; whether the intensity at which an electric current might cease to act would be the same for all bodies; and also whether the electrolytes, when thus resisting decomposition, would conduct the electricity as a metal or charcoal does, after they ceased to conduct as electrolytes, or would act as insulators. It is first proved with regard to water, that a current of a certain intensity is necessary for its decomposition, but that a current of a lower intensity is conducted by it; and that with such feeble currents, pure water conducts as well as acidulated water or saline solutions. The same condition of a certain necessary intensity of current was found to hold good also with sulphate of soda in solution with fused chloride of lead and other bodies, and is considered by analogy as extending to all electrolytes.

In the *third* part of the paper, associated voltaic circles, or the voltaic battery, is examined. From the principles and facts stated in the preceding parts, it appears evident that the association of many pairs of plates, equal in size, nature and force, cannot by any possibility increase the quantity of electricity above that which any single pair in the series could produce, taking the quantity of zinc oxidized at any one plate as the standard of development. It is easy, by using amalgamated zinc, to construct a battery in which no action shall take place on the metals, except the extremities be in communication. If a battery of ten pairs of plates be thus communicated, there is of course oxidation of each zinc plate, and a current of electricity circulates. If the contact of the extremities be continued until a certain quantity of zinc has been dissolved at any one plate, it will be found that an exactly equal quantity has been dissolved at each of the other plates; and that a certain quantity of electricity has passed, which can be taken cognizance of by the volta-electrometer. But should nine of the pairs of plates be removed and the battery be reduced to a single pair, yet when the given quantity of zinc had been dissolved there, as much electricity would have gone round the circuit as with the whole number of ten pairs, and during the evolution of which ten times the quantity of zinc had been oxidized.

This result, already proved by electro-magnetic experiments, is shown to be a necessary consequence of the construction of the pile and the manner in which its forces act. The electricity evolved by

chemical action at one pair of plates cannot pass by another pair except an equal chemical action take place there; and as the chemical and electrical action are always equivalent, the equal chemical action at the second pair will do no more than suffice to transfer forwards the forces disturbed at the first pair, and can add nothing to their quantity: but they can add to their *intensity*, and in fact the recurrence of a second chemical action at the second pair of plates has exactly the same effect as would be produced by a more intense chemical action at the first pair. In this way it is that numbers of plates give energy to the voltaic pile, and enable its power to penetrate electrolytic bodies and permeate bad conductors in a manner which could not be done by the electricity of a few pairs of plates only.

The *fourth* part of the paper relates to the resistance opposed to the electric current at the place of decomposition, and refers this at once to the resistance of the chemical affinity which has to be overcome. This of course varies with the number of places where decomposition is effected, the strength of the affinity of the elements of the decomposing body for each other, and the nature of the substance against which the decomposition is effected, and by which it may very frequently be assisted. All these are taken into account, their general, and occasionally particular, results shown, and their perfect harmony with the principles previously advanced pointed out.

In the last part of the paper some general remarks on the active voltaic battery are made, in which the influence of several distinct causes in producing a rapid change and deterioration of action is pointed out. Each of these causes is considered separately, and the effects they produce are shown to be necessary consequences of the principles already laid down as those of the voltaic battery.

The following Papers were then read:

1. "Observations on the *Teredo navalis* and *Limnoria terebrans*, as at present existing in certain localities of the British Islands." By William Thompson, Esq., Vice-President of the Natural History Society of Belfast. Communicated by J. G. Children, Esq. Sec. R.S.

The opinion which has been advanced, that the *Teredo navalis* is no longer to be found on the British coast, is shown by the author to be erroneous; for numerous specimens of that destructive animal, collected from the piles used in the formation of the pier at Portpatrick in Ayrshire, were furnished to him by Captain Frayer, R.N. (of His Majesty's Steam-packet Spitfire). Some of these specimens had attained the length of nearly two feet and a half, a magnitude at least equal to, if not exceeding, the largest brought from the Indian seas. After giving a description of the animal, the author enters into an inquiry into the agency it employs to perforate the timber which it consumes as food, and in which it establishes its habitation. He ascribes to the action of a solvent, applied by the proboscis, the smooth and rounded termination of its cell, which is afterwards enlarged by the mechanical action of the primary valves.

The author then gives an account of the natural history and opera-